PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark Office, PCT
2011 South Clark Place Room CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 30 January 2001 (30.01.01)	
International application No. PCT/FI00/00542	**Applicant's or agent's file reference** VAI 81 PCT
International filing date (day/month/year) 15 June 2000 (15.06.00)	**Priority date** (day/month/year) 17 June 1999 (17.06.99)
Applicant STORMBOM, Lars et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

17 November 2000 (17.11.00)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer R. E. Stoffel
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference VAI 81 PCT	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/FI00/00542	International filing date *(day month year)* 15.06.2000	Priority date *(day/month/year)* 17.06.1999
International Patent Classification (IPC) or national classification and IPC7 G 01 N 27/02, G 01 N 27/22, G 01 N 33/28		
Applicant VAISALA OYJ ET AL		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 4 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 3 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
17.11.2000	07.09.2001
Name and mailing address of the IPEA/SE Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Facsimile No. 08-667 72 88	Authorized officer Jonas Andersson/LR Telephone No. 08-782 25 00

Form PCT/IPEA/409 (cover sheet) (January 1998)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/FI00/00542

I. Basis of the report

1. With regard to the **elements** of the international application:*

☐ the international application as originally filed

☒ the description:
pages 1-10 , as originally filed
pages _____ , filed with the demand
pages _____ , filed with the letter of _____

☒ the claims:
pages _____ , as originally filed
pages _____ , as amended (together with any statement) under article 19
pages _____ , filed with the demand
pages 11-13 , filed with the letter of 24.08.2001

☒ the drawings:
pages 1 , as originally filed
pages _____ , filed with the demand
pages _____ , filed with the letter of _____

☐ the sequence listing part of the description:
pages _____ , as originally filed
pages _____ , filed with the demand
pages _____ , filed with the letter of _____

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language _____ which is:

☐ the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).

☐ the language of publication of the international application (under Rule 48.3(b)).

☐ the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

☐ contained in the international application in written form.

☐ filed together with the international application in computer readable form.

☐ furnished subsequently to this Authority in written form.

☐ furnished subsequently to this Authority in computer readable form.

☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. ☐ The amendments have resulted in the cancellation of:

☐ the description, pages _____

☐ the claims, Nos. _____

☐ the drawings, sheet/fig _____

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2 (c)).**

* *Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

** *Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.*

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-14	YES
	Claims		NO
Inventive step (IS)	Claims	1-14	YES
	Claims		NO
Industrial applicability (IA)	Claims	1-14	YES
	Claims		NO

2. Citations and explanations (Rule 70.7)

The invention relates to a method and an apparatus for measurement of water content of a liquid by simultaneously performing two different electrical measurements. Properties of the liquid are measured using both a relative-value measurement and an absolute-value measurement. The apparatus of the invention comprises one sensor sensitive to changes in dielectric coefficient and another sensor sensitive to relative water content.

The invention is intended to solve the problem concerning determination of water content in oil, which usually require a zeroing step that is temperature dependent.

The method according to amended claims 1-8 further comprises the repetition of the measurement at two different temperatures in a rapid succession at a constant water content. The apparatus according to amended claims 9-14 also defines that the sensor means adapted for measuring the relative water content contains an auxiliary medium capable of absorbing water contained in the liquid under measurement. These features are not revealed by the prior art documents cited in the International Search Report and there is no hint in these documents leading a person skilled in the art to the solution according to present invention.

Consequently, the invention according to amended claims 1-14 is novel, industrially applicable, and is considered to involve an inventive step.

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

The independent claim 1 is not considered to fulfil the requirement on clarity and conciseness. Expressions like "a property of the liquid is measured electrically for one parameter" and "another electrical method" are too broad and do not define how the invention is actually performed. Further, the expression "measurement method resulting in the measurement of the liquid for its dielectric coefficient and relative water content" of claim 1 is directed to a result to be obtained without clearly defining how this is actually done.

Claim 1 is further unclear since it presents the wish that "said measurement is repeated at two different temperatures in a so rapid succession that the water content of the liquid may be assumed to stay at least substantially constant". This expression is vague and does not give a clear definition on how rapid the measurement should be repeated.

Consequently, the subject matter of claim 1 should be clarified in order to define all the features needed to obtain the result in view.

The Swedish Patent Office
PCT International Application

What is claimed is:

Sub B1

1. Method for measurement of water content of a liquid, in which method a property of the liquid is measured electrically for one parameter,

- the properties of the liquid are measured at least substantially simultaneously also by another electrical method, whereby the properties of the liquid are measured using both a relative-value measurement method and an absolute-value measurement method resulting in the measurement of the liquid for its dielectric coefficient and relative water content

c h a r a c t e r i z e d in that

- said measurement is repeated at two different temperatures in a so rapid succession that the water content of the liquid may be assumed to stay at least substantially constant.

2. Method according to claim 1, c h a r a c t e r i z e d in that the temperature dependence of the dielectric coefficient of an entirely dry liquid is determined by measuring essentially simultaneously the ε_r and temperature of the liquid at at least two temperatures.

Sub. B2

3. Method according to claim 1 or 2, c h a r a c t e r i z e d in that said relative water content measurement is carried out using a capacitive sensor.

4. Method according to any one of foregoing claims, c h a r a c t e r i z e d in that changes in the results of water content measurement due to aging of the liquid are compensated for by virtue of using only the most recent data of the measurement history for the compensation for changes in the response of the measurement system.

AMENDED SHEET

The Swedish Patent Office
PCT international Application

Sub A3 Cont'd

5. Method according to any one of foregoing claims, c h a r a c t e r i z e d in that the aging of said liquid, advantageously oil, is indicated on the basis of changes in the value of ε_0.

6. Method according to any one of foregoing claims, c h a r a c t e r i z e d in that, in the measurement of relative water content, an auxiliary medium is used for absorbing thereto the water contained in the liquid under measurement.

Sub B1

7. Method according to claim 5, c h a r a c t e r i z e d in that said auxiliary medium is a thin-film polymer layer.

Sub A3

8. Method according to claim 5 or 6, c h a r a c t e r i z e d in that the water content of said auxiliary medium is determined by way of measuring its dielectric coefficient.

Sub B1

9. Apparatus for measurement of the water content of a liquid, said apparatus comprising one electrical sensor means (5, 6 or 1, 6) for measuring the water content of a liquid, which apparatus includes

- a second electrical sensor means (1, 6 or 5, 6) for measuring the water content of a liquid, said second sensor means (1, 6 or 5, 6) measuring a different parameter than that measured by said first electrical sensor means (5, 6 or 1, 6), said sensor means being such that one of them measures the properties of the liquid by a relative-value measurement method and the other by an absolute-value measurement method, whereby one sensor means (5, 6) is sensitive to changes in the dielectric coefficient and the other sensor means is sensitive to the relative water content,

c h a r a c t e r i z e d in that

The Swedish Patent Office
PCT International Application

– the sensor means adapted for measuring the relative water content contain an auxiliary medium capable of absorbing water contained in the liquid under measurement.

10. Apparatus according to claim 9, characterized in that said sensor means (5, 6) sensitive to changes in dielectric coefficient is formed by two interdigitated finger electrodes (5, 6).

11. Apparatus according to claim 9 or 10, characterized in that one electrode (6) of the sensor pair adapted to perform the measurement of dielectric coefficient also forms a part of the measurement electrode pair (1, 6) adapted to perform the measurement of the relative water content.

12. Apparatus according to claim 9, characterized in that the sensor means sensitive to changes in the dielectric coefficient is formed by a coaxial structure, wherein one electrode is formed by a center pin and the jacket has a net-like structure and is permeable to water.

13. Apparatus according to claim 12, characterized in that said auxiliary medium is a thin-film polymer layer.

14. Apparatus according to claim 12 or 13, characterized in that the apparatus contains means adapted to measure the dielectric coefficient of said auxiliary medium whereupon the relative water content of said auxiliary medium can be determined.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 00/00542

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G01N 27/02, G01N 27/22, G01N 33/28
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 9923469 A1 (MULTI-FLUID INC.), 14 May 1999 (14.05.99), page 2, line 15 - line 17; page 3, line 24 - line 30; page 13, line 1 - line 21, page 16, line 14 - line 18	1-2,4-5,9-11
A	--	3, 6-8,12-15
A	US 5331287 A (FREDERID G. YAMAGISHI ET AL), 19 July 1994 (19.07.94)	6-8,10,13-15
A	--	
A	US 4129501 A (EDWARD M. HAYNES), 12 December 1978 (12.12.78)	6-8,13-15
	--	

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 October 2000	26 October 2000 (26.10.00)
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Jonas Andersson/GH Telephone No. +46 8 782 25 00

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 00/00542

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5644239 A (JOSEPH Y. HUANG ET AL), 1 July 1997 (01.07.97) --	3
A	EP 0141636 A1 (ANDERSON STRATHCLYDE PLC.), 15 May 1985 (15.05.85) --	12
A	WO 9846984 A2 (PALL CORPORATION), 22 October 1998 (22.10.98), page 7, line 10 - line 28 --	10
A	DE 19647201 C1 (KIMMERLE, KLAUS, DR,-ING ET AL), 12 February 1998 (12.02.98) --	10

INTERNATIONAL SEARCH REPORT

Information on patent family members

03/10/00

International application No.
PCT/FI 00/00542

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9923469 A1	14/05/99	AU 1121799 A	24/05/99
US 5331287 A	19/07/94	DE 69326726 D,T	29/06/00
		EP 0584557 A,B	02/03/94
		JP 2610775 B	14/05/97
		JP 6160319 A	07/06/94
US 4129501 A	12/12/78	NONE	
US 5644239 A	01/07/97	WO 9528645 A	26/10/95
EP 0141636 A1	15/05/85	GB 2149117 A	05/06/85
		GB 8329483 D	00/00/00
		ZA 8408489 A	26/03/86
WO 9846984 A2	22/10/98	EP 0975955 A	02/02/00
DE 19647201 C1	12/02/98	NONE	

RECORD COPY

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PCT REQUEST

Original (for **SUBMISSION**) - printed on 15.06.2000 08:47:36 AM

0 0-1	**For receiving Offic use only** International Application No.	PCT/FI 0 0 / 0 0 5 4 2
0-2	International Filing Date	1 5 JUN 2000 (15-06-2000)
0-3	Name of receiving Office and "PCT International Application"	The Finnish Patent Office PCT International Application
0-4 0-4-1	**Form - PCT/RO/101 PCT Request** Prepared using	PCT-EASY Version 2.90 (updated 10.05.2000)
0-5	**Petition** The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty	
0-6	**Receiving Office (specified by the applicant)**	National Board of Patents and Registration (Finland) (RO/FI)
0-7	**Applicant's or agent's file reference**	VAI 81 PCT
I	**Title of invention**	METHOD AND APPARATUS FOR MEASURING WATER CONTENT
II	**Applicant**	
II-1	This person is:	applicant only
II-2	Applicant for	all designated States except US
II-4	Name	VAISALA OYJ
II-5	Address:	P.O. Box 26 FIN-00421 Helsinki Finland
II-6	State of nationality	FI
II-7	State of residence	FI
II-8	Telephone No.	+358-9-894 91
II-9	Facsimile No.	+358-9-894 9227
III-1	**Applicant and/or inventor**	
III-1-1	This person is:	applicant and inventor
III-1-2	Applicant for	US only
III-1-4	Name (LAST, First)	STORMBOM, Lars
III-1-5	Address:	Raappavuorenreuna 2 A 2 FIN-01620 Vantaa Finland
III-1-6	State of nationality	FI
III-1-7	State of residence	FI

PCT REQUEST

Original (for **SUBMISSION**) - printed on 15.06.2000 08:47:36 AM

III-2	**Applicant and/or inventor**	
III-2-1	This person is:	applicant and inventor
III-2-2	Applicant for	US only
III-2-4	Name (LAST, First)	LYYRA, Matti
III-2-5	Address:	Aamutie 3 B 2 FIN-01670 Vantaa Finland
III-2-6	State of nationality	FI
III-2-7	State of residence	FI
III-3	**Applicant and/or inventor**	
III-3-1	This person is:	applicant and inventor
III-3-2	Applicant for	US only
III-3-4	Name (LAST, First)	LEPPÄNEN, Jukka
III-3-5	Address:	Kasavuorentie 1 as. 1 FIN-02700 Kauniainen Finland
III-3-6	State of nationality	FI
III-3-7	State of residence	FI
IV-1	**Agent or common representative; or address for correspondence** The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as:	agent
IV-1-1	Name	SEPPO LAINE OY
IV-1-2	Address:	Itämerenkatu 3 B FIN-00180 Helsinki Finland
IV-1-3	Telephone No.	+358-9-68 59 560
IV-1-4	Facsimile No.	+358-9-68 595 610
IV-1-5	e-mail	seppo.laine@selpat.fi
V	**Designation of States**	
V-1	Regional Patent (other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)	EP: AT BE CH&LI CY DE DK ES FI FR GB GR IE IT LU MC NL PT SE and any other State which is a Contracting State of the European Patent Convention and of the PCT
V-2	National Patent (other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)	JP US

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V-5	**Precautionary D signation Stat ment** In addition to the designations made under items V-1, V-2 and V-3, the applicant also makes under Rule 4.9(b) all designations which would be permitted under the PCT except any designation(s) of the State(s) indicated under item V-6 below. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit.		
V-6	**Exclusion(s) from precautionary designations**	NONE	
VI-1	**Priority claim of earlier national application**		
VI-1-1	Filing date	17 June 1999 (17.06.1999)	
VI-1-2	Number	991391	
VI-1-3	Country	FI	
VI-2	**Priority document request** The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) identified above as item(s):	VI-1	
VII-1	**International Searching Authority Chosen**	Swedish Patent Office (ISA/SE)	
VIII	**Check list**	number of sheets	electronic file(s) attach d
VIII-1	Request	4	-
VIII-2	Description	8	-
VIII-3	Claims	3	-
VIII-4	Abstract	1	vai81pct.txt
VIII-5	Drawings	1	-
VIII-7	TOTAL	17	
	Accompanying items	paper document(s) attached	electronic file(s) attached
VIII-8	Fee calculation sheet	✓	-
VIII-16	PCT-EASY diskette	-	diskette
VIII-17	Other (specified):	Copy of official action	-
VIII-18	**Figure of the drawings which should accompany the abstract**	1	
VIII-19	**Language of filing of the international application**	Finnish	
IX-1	**Signature of applicant or agent**		
IX-1-1	Name	SEPPO LAINE OY	
IX-1-2	Name of signatory	Jarkko Tiilikainen	

FOR RECEIVING OFFICE USE ONLY

10-1	**Date f actual rec ipt of th purp rted internati nal applicati n**	15 JUN 2000	(15-06-2000)

PCT REQUEST

VAI 81 PCT

Original (for **SUBMISSION**) - printed on 15.06.2000 08:47:36 AM

10-2 10-2-1 10-2-2	**Drawings:** Received Not received	
10-3	**Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application**	
10-4	**Date of timely receipt of the required corrections under PCT Article 11(2)**	
10-5	**International Searching Authority**	ISA/SE
10-6	**Transmittal of search copy delayed until search fee is paid**	

FOR INTERNATIONAL BUREAU USE ONLY

11-1	**Date of receipt of the record copy by the International Bureau**	07 JULY 2000 (07.07.00)

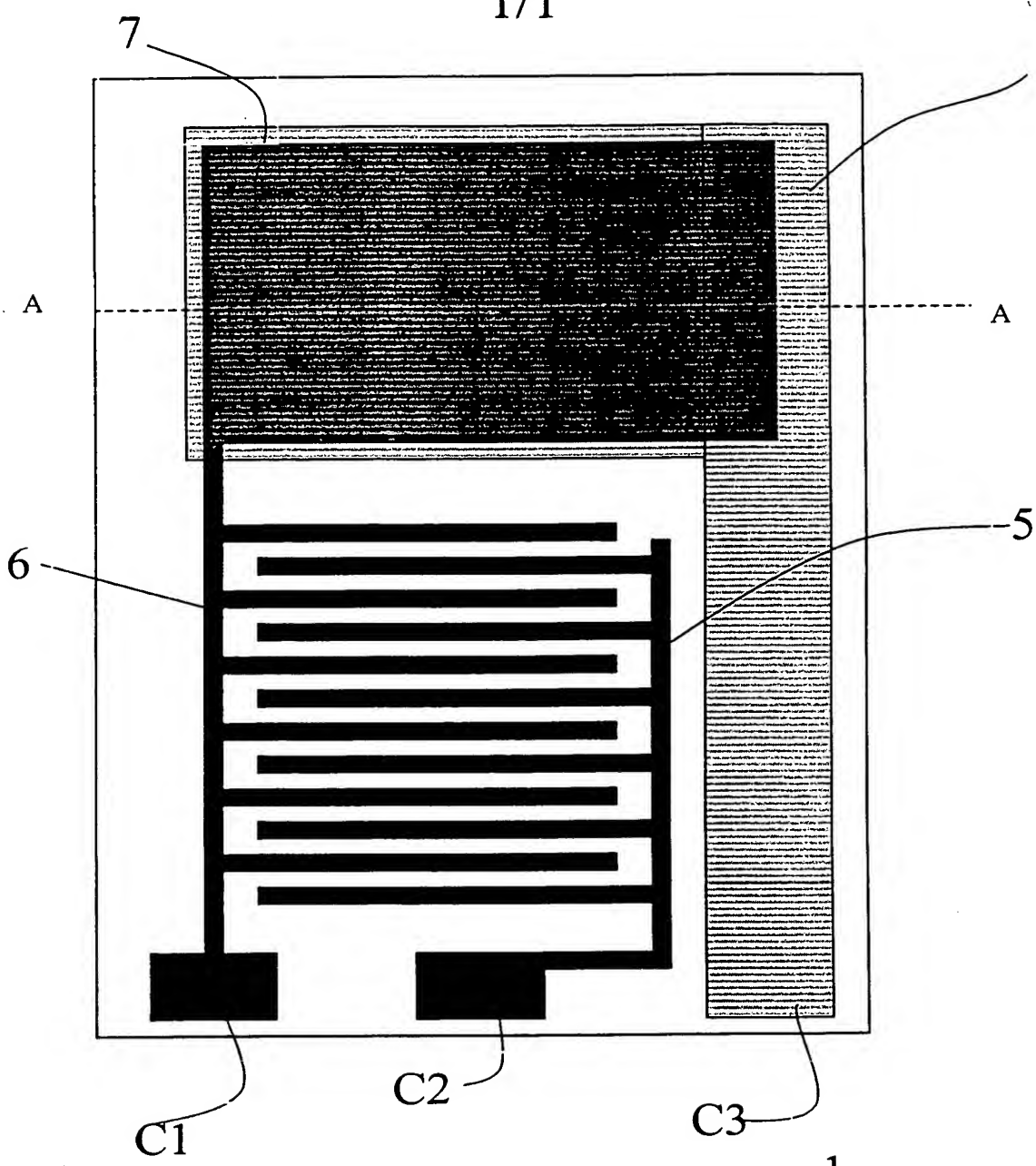

Fig. 1

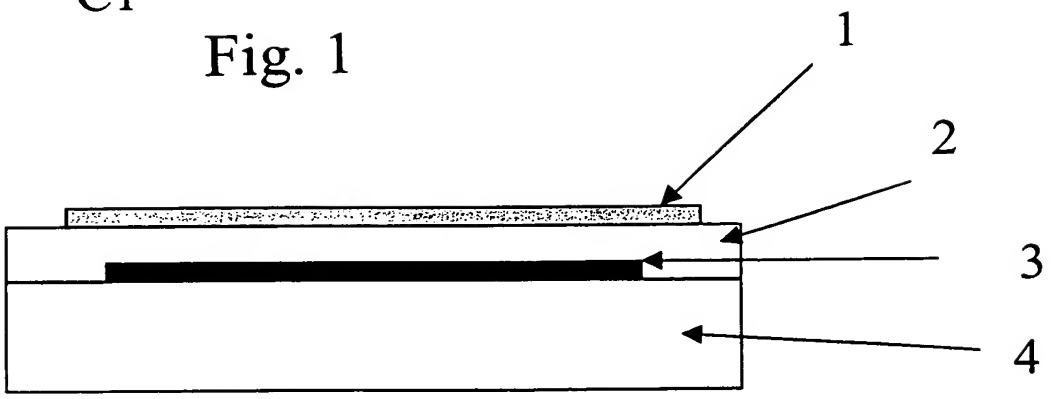

Fig. 2

Menetelmä ja laitteisto nesteen vesipitoisuuden mittausta varten

Keksinnön kohteena on patenttivaatimuksen 1 johdannon mukainen menetelmä nesteen vesipitoisuuden mittausta varten.

Keksinnön kohteena on myös laitteisto nesteen vesipitoisuuden mittausta varten.

US-patentissa 5331287 kuvataan sensori, jossa interdigitoidut elektrodit (sormielektrodit) on päällystetty johdepolymeerillä. Öljyssä oleva vesi hydraa polymeerin ja muuttaa sen johtavuutta. Havaitsee myös mahdolliset hapot protonoinnin kautta.

US-patentissa 5642098 kuvataan rengasoskillaattorikytkentä, jossa useamman, samaa parametria mittaavan mittapään avulla mitataan öljyn sähköisiä ominaisuuksia.

US-patentissa 5644239 mitataan nesteen (öljyn) sähkönjohtavuus kahdessa korotetussa lämpötilassa. Lisäksi mitataan mahdollisesti optisesti öljyn "opacity" (sameus). Näiden parametrien avulla lasketaan öljyn "laatuluku".

US-patentissa 5656767 kuvataan sensorijärjestelmä, jossa mitataan öljyn sähköisen suureen (esim. kapasitanssin) muutosta ajan funktiona. Referenssisuureena voidaan käyttää puhdasta (kuiva) samaa öljyä. Monia variaatiota samasta teemasta jossa esim. lämmitetään näytettä yms.

Tunnetussa tekniikassa on useita puutteellisuuksia. Yleisiä koko alueen 0-100 % absoluuttitilavuusvesipitoisuuden mittausmenetelmiä ovat dielektrisyysvakion mittaus ja IR-absorption mittaus. Yhteistä molemmille menetelmille on se, että niissä tarvitaan mittarin nollaus, ts. täytyy säätää mittaus näyttämään 0-pitoisuutta kun anturissa on täysin kuivaa (vedetöntä) nestettä. Tämä voidaan hoitaa joko kertaluontoisena säätönä tai pitämällä sensorissa täysin kuivaa vertailuöljyä.

Lisävaikeutena on että tämä 0-säätö tyypillisesti on lämpötilasta riippuva.

0-arvo voi myös muuttua muun kun veden vaikutuksesta nesteen vanhetessa.

Absoluuttimenetelmät ovat vahvoilla kun vesipitoisuudet ovat isoja (%-luokassa).

Pienillä pitoisuuksilla ongelmana on yleensä mittausherkkyys ja offset-epämääräisyydet (nollaus-virhe).

Suhteellisella (aw-) menetelmällä saadaan tieto vesipitoisuudesta verrattuna saturaatiotilaan. Muunnos absoluuttiseen volyymiprosenttiin on kuitenkin tuntematon ellei k.o. nesteen muunnoskerrointa ole määritetty. Aw-menetelmä on toimiva matalissa vesipitoisuuksissa (ei saturoitunut tila, ei emulsiotila), joissa saavutetaan riittävä mittausherkkyys. Myöskään nollausvirhettä ei ole.

Tämän keksinnön tarkoituksena on poistaa edellä kuvatun tekniikan puutteellisuudet ja aikaansaada aivan uudentyyppinen menetelmä ja laitteisto nesteen vesipitoisuuden mittausta varten.

Keksintö perustuu siihen, että mitataan öljyn/nesteen vesipitoisuutta samanaikaisesti kahdella eri menetelmällä, jolloin mittausmenetelminä käytetään absoluuttimenetelmää ja suhteellista mittausmenetelmää.

Täsmällisemmin sanottuna keksinnön mukaiselle menetelmälle on tunnusomaista se, mikä on esitetty patenttivaatimuksen 1 tunnusmerkkiosassa.

Keksinnön mukaiselle laitteistolle on puolestaan tunnusomasta se, mikä on esitetty patenttivaatimuksen 9 tunnusmerkkiosassa.

Keksinnön avulla saavutetaan huomattavia etuja.

Yhdistämällä absoluuttimenetelmään suhteellinen menetelmä (aw-mittaus) voidaan poistaa absoluuttimenetelmän nollauksen tarve.

Käyttämällä nopeasti toistettuja mittauksia eri lämpötiloissa, voidaan myös lämpötilan muutoksista aiheutuvat virheet eliminoida.

Keksintöä ryhdytään seuraavassa lähemmin tarkastelemaan oheisten kuvioiden mukaisten suoritusesimerkkien avulla.

Kuvio 1 esittää yläkuvantona yhtä keksinnön mukaista elektrodirakennetta.

Kuvio 2 esittää leikkausta A-A kuvion 1 mukaisesta anturirakenteesta.

Kuvion 1 ja 2 mukaisesti keksinnön mukainen ratkaisu on toteutettavissa rakenteella, jossa substraatin 4 pinnalle on muodostettu kolme elektrodia. Itse substraatin 4 pinnalla on alaelektrodipari 3, joka on muodostettu elektrodeista 5 ja 6. Tässä tapauksessa elektrodit ovat ns. sormielektrodit eli interdigitoidut elektrodit, jossa mahdollisimman suuri elektrodien välinen pinta on muodostettu elektrodirakenteella, joka vastaa toistensa lomissa olevia sormia. Elektrodien 5 ja 6 toisiaan lähinnä olevien reunojen pituus vastaa tasokondensaattorirakenteen elektrodipinnan pinta-alaa. Elektrodien 5 ja 6 leveys samoin kuin niiden välinen matka (gap) on tyypillisesti 5-500 mikrometriä. Sormirakenteen lisäksi elektrodissa 6 on tasomainen alue 7. Elektrodit 5 ja 6 käsittävät myös kontaktialueet C1 ja C2 elektrodien kytkemiseksi edelleen mittalaitteisiin. Alaelektrodiparin 3 päälle on muodostettu polymeerikalvo 2, jonka paksuus on tyypillisesti 0,5-5 mikrometriä. Polymeerikalvo 2 voi ulottua myös sormielektrodirakenteen 5 ja 6 päälle, jolloin se toimii passivointina ja vähentää nesteen johtavien partikkelien vaikutusta mittaukseen. Polymeerikalvon 2 päällä on vettä läpäisevä yläelektrodi 1, jonka kontaktipisteenä toimii kontakti C3. Yläelektrodi 1 on sijoitettu elektrodin 6 suorakaidemaisen yhtenäisen alueen 7 päälle tasokondensaattorirakenteen muodostamiseksi.

Kuvioiden 1 ja 2 rakennetta käytetään seuraavasti. Nesteen dielektrisyysvakio mitataan käyttäen elektrodien 5 ja 6 kontakteja C1 ja C2. Suhteellinen mittaus puolestaan toteutetaan elektrodien 6 ja 1 välillä, siis kontakteista C1 ja C3.
Neste, jonka vesipitoisuutta mitataan on edullisesti öljyä, mutta myös muiden nesteiden kuten hydrauliikkanesteen, bensiinin tai jäähdytysnesteen vesipitoisuutta voidaan mitata keksinnön mukaisesti.

Keksinnön mukaisesti vedenaktiviteettimittaus voidaan toteuttaa seuraavasti.

Vedenaktiviteettimittaus on vain yksi esimerkki keksinnön mukaisesta suhteellisen pitoisuuden mittauksesta.

Anturi voi olla esim. kuvioiden 1 ja 2 mukaisesti kahden elektrodin välillä oleva polymeerikalvo 2, joka absorboi vettä ympäristön vesiaktiviteetin funktiona. Tällaisia antureita ovat esim. suhteellisen kosteuden anturit. Tyypillistä tällaiselle mittausmenetelmälle on että mittauksen tuloksena saadaan veden aktiviteetti ts:

$aw=F(ppm/ppm_s(T))$, missä (1)

ppm=veden tilavuusosuus liuoksessa$*10^6$

ppm_s=veden tilavuusosuus kylläisessä liuoksessa $*10^6$

Funktio F voidaan esim. olettaa lineaariseksi jolloin:

$aw=ppm/ppm_s(T)$ (2)

aw vaihtelee välillä 0 (täysin kuiva neste) ... 1 (kylläinen vesiliuos).

Pelkällä vedenaktiviteettimittauksella saadaan tieto siitä kuinka lähellä ollaan emulsio- tai vapaan veden tilaa. Kun emulsio- tai vapaan veden tila on saavutettu, vedenaktiviteetti on kuitenkin hyvin lähellä arvoa 1 jolloin nesteen tilasta ei saada informaatiota. Mittausperiaatteella saadaan kuitenkin pitoisuuksissa $aw < 0,9$ hyvin herkkä öljy/nestetyypistä riippumaton tieto esim. sen voiteluominaisuuksista.

Huonelämpötilassa ppm_s voi vaihdella välillä 20 ppm lisäaineistamattomalle perusöljylle aina yli 10000 ppm:n asti runsaasti lisäaineistetulle voiteluöljylle.

Dielektrisyysvakiomittausta kuvataan seuraavassa tarkemmin. Dielektrisyysvakiomittaus on vain yksi esimerkki keksinnön piiriin kuuluvista absoluuttipitoisuusmittauksista.

Nesteen dielektrisyysvakiomittauksessa voi anturi olla keksinnön mukaisesti interdigitoitu elektrodi (sormielektrodi) kuvioiden 1 ja 2 mukaisesti tai koaksiaalinen elektrodipari, joka on kosketuksissa mitattavan nesteen kanssa. Anturista saatava signaali on riippuvainen sekä mitattavan nesteen dielektrisyysvakiosta että sen vesipitoisuudesta:

$\varepsilon_r=\varepsilon_0+F(ppm)$, missä (3)

ε_0=Täysin kuivan nesteen dielektrisyysvakio

F(ppm)=veden määrästä riippuva funktio. Voidaan rajoitetulla pitoisuusalueella olettaa lineaariseksi eli:

$\varepsilon_r=\varepsilon_0+a*ppm$, missä (4)

a = nestetyypistä riippumaton vakio

Dielektrisyysmittauksen hyvä puoli on se, että se kattaa koko mahdollisen mittausalueen 0-100 tilavuus % vettä. Haittapuolena mittausmenetelmässä on se, että herkkyys kuivassa päässä (joka yleensä on kiinnostavin) on pieni ja että ε_0 on tunnettava. Tyypillisesti mittaus kalibroidaan käyttämällä kuivattua öljyä.

Jos molempia mittausmenetelmiä käytetään samanaikaisesti voidaan toimia useammalla tavalla nesteen kalibroimiseksi:

Mikäli nesteen $ppm_s(T)$ tunnetaan, toimitaan seuraavasti:

Mitataan samanaikaisesti aw ja ε_r. Jos aw on alle 1 voidaan olettaa yhtälöiden 2 ja 4 pätevän.

Yhdistämällä yhtälöt 2 ja 4 saadaan ratkaistua ε_0 ja ppm. $ppm_s(T)$ voidaan myös arvioida, jos nestetyyppi on tunnettu, jolloin saadaan jonkun verran epätarkempi tulos.

Mikäli nesteen $ppm_s(T)$ on tuntematon, toimitaan seuraavasti:

Mitataan vasteet kahdella eri (tuntemattomalla) vesipitoisuudella. Jos molemmissa tapauksissa aw on alle 1 saadaan yhtälöryhmä, jossa on neljä yhtälöä ja neljä tuntematonta eli ratkaisu on yksikäsitteinen. Jos merkitään mittaustuloksia mittauskerroilla 1 ja 2 vastaavilla alaindekseillä saadaan:

$$\varepsilon_0=(aw_2*\varepsilon_{r1}- aw_1*\varepsilon_{r2})/(aw_2- aw_1) \qquad (5)$$

Tämä toimenpide voi tapahtua myös automaattisesti mittalaitteen toimiessa jos mitattavan nesteen kosteuspitoisuus vaihtelee.

Jos dataa kerätään enemmän kuin kaksi mittausparia, voidaan tuntemattomat termit sovittaa dataan esim. pienimmän neliösumman menetelmää käyttäen.

Jälkimmäisen menetelmän vahvuutena on, että lisäksi että mahdolliset muutokset ε_0:ssa tai $ppm_s(T)$:ssa lämpötilamuutosten tai nesteen vanhenemisen tai likaantumisen vuoksi voidaan kompensoida. Öljyn ikääntymistä voidaan indikoida ε_0 :n muutoksesta.

Jos öljynäytteen lämpötilaa muutetaan tai näytevirtauksen lämpötilaa muutetaan niin nopeasti, että voidaan olettaa vesipitoisuuden pysyvän likimain vakiona voidaan määrittää täysin kuivan nesteen dielektrisyysvakion lämpötilariippuvuus mittaamalla lähes samanaikaisesti ε_r ja nesteen lämpötila ainakin kahdessa lämpötilassa.

Esimerkiksi voimme olettaa ε_0 olevan lineaarinen lämpötilan funktio:

$$\varepsilon_r=b0+b1*T+a*ppm \qquad (6)$$

tällöin voimme muodostaa

$$\varepsilon_r(T2)- \varepsilon_r(T2)=b1*(T2-T1) \qquad (7)$$

josta on b1-kerroin ratkaistavissa. Tässäkin tapauksessa voi käyttää useampaa lämpötilapistettä ja pienimmän neliösumman menetelmää. Tällä tavalla saadaan jatkuvasti luotettava arvio ε_0-parametrille lämpötilan muuttuessa.

Samanaikaisesti voidaan määrittää myös $ppm_s(T)$:n lämpötilariippuvuus. Yleisesti voidaan olettaa rajatulla lämpötila-alueella:

$$ppm_s(T)=c0*e^{(C1*T)} \qquad (8)$$

Jossa

c0= ppm_s:n arvo kun T=0°C
c1=lämpötilariippuvuuskerroin

Tällöin voidaan mittaamalla aw ainakin kahdessa lämpötilassa ratkaista c1 oletuksella ettei nesteen vesipitoisuus muutu:

$$c1=LN(aw1/aw2)/(T2-T1) \qquad (9)$$

Edullisesti nämä kaksi määritystä voidaan suorittaa samanaikaisesti.

Keksinnön yhden edullisen suoritusmuodon mukaisesti suoritetaan nollaus automaattisesti aina kun aw-mittaus antaa riittävän pienen arvon. Mitä pienempi aw-arvo on sitä tarkempi nollaus saadaan. Epävarmuus menetelmässä liittyy $ppm_s(T)$:n arvoon joka on nestetyypistä riippuva ja "arvattava".

Keksinnön toisen edullisen sovellusmuodon mukaisesti on käytettävissä kaksi näytettä nesteestä/öljystä eri vesipitoisuuksilla. Joko näytetään laitteelle tietoisesti kaksi eri vesipitoisuudella olevaa näytettä tai kerätään prosessista vähitellen dataa ja käytetään prosessissa tapahtuvaa luonnollista vesipitoisuuden vaihtelua. Saamme arvon myös $ppm_s(T)$:lle jolloin voimme laskea keksinnön mukaisesti aw-arvosta myös ppm vesipitoisuuden, joka ei perustu "arvaukseen".

Jos kerätään dataa jatkuvasti prosessista ja samalla "unohdetaan" dataa vanhemmasta päästä, voidaan kompensoida myös nesteen/öljyn vanhenemisesta johtuvia muutoksia sekä ppm_s.:ssä että ε_0:ssa.

Jos prosessissa lisäksi tapahtuu lämpötilamuutoksia voimme myös saada arvot ppm_s.:ssä että ε_0:n lämpötilariippuvuudesta.

Patenttivaatimukset:

1. Menetelmä nesteen vesipitoisuuden mittausta varten, jossa menetelmässä mitataan nesteen ominaisuutta sähköisesti yhdellä parametrilla,

t u n n e t t u siitä, että

- nesteen ominaisuuksia mitataan ainakin likimain samanaikaisesti myös toisella sähköisellä menetelmällä, jolloin nesteen ominaisuuksia mitataan suhteellisella ja absoluuttimenetelmällä siten, että nesteestä mitataan dielektrisyysvakio sekä veden suhteellinen pitoisuus.

2. Patenttivaatimuksen 1 mukainen menetelmä, t u n n e t t u siitä, että mittaus toteutetaan kapasitiivisella anturilla.

3. Jonkin edellisen patenttivaatimuksen mukainen menetelmä, t u n n e t t u siitä, että mittaus toistetaan kahdessa eri lämpötilassa niin nopeasti, että vesipitoisuuden voidaan olettaa pysyvän ainakin olennaisesti vakiosuuruisena.

4. Jonkin edellisen patenttivaatimuksen mukainen menetelmä, t u n n e t t u siitä, että nesteen vanhenemisesta aiheutuvia muutoksia vesipitoisuuden mittaukseen kompensoidaan käyttämällä vain tuoreinta mittaushistoriatietoa mittarin mittausarvon kompensointiin.

5. Jonkin edellisen patenttivaatimuksen mukainen menetelmä, t u n n e t t u siitä, että nesteen, edullisesti öljyn ikääntymistä indikoidaan ε_0:n muutoksista.

6. Jonkin edellisen patenttivaatimuksen mukainen menetelmä, t u n n e t t u siitä, että veden suhteellista pitoisuutta mitattaessa imeytetään mitattavassa nesteessä olevaa vettä apuväliaineeseen.

7. Patenttivaatimuksen 6 mukainen menetelmä, t u n n e t t u siitä, että apuväliaine on polymeeriohutkalvo.

8. Patenttivaatimuksen 6 tai 7 mukainen menetelmä, t u n n e t t u siitä, että apuväliaineen vesipitoisuus mitataan dielektrisyysvakion avulla.

9. Laitteisto nesteen vesipitoisuuden mittaamiseksi, joka laitteisto käsittää yhden sähköisen mittauselimen (5, 6 tai 1, 6) nesteen vesipitoisuuden mittaamiseksi,

t u n n e t t u siitä, että

– laitteistossa on myös toinen sähköinen mittauselin (1, 6 tai 5, 6) nesteen vesipitoisuuden mittaamiseksi, joka toinen mittauselin (1, 6 tai 5, 6) mittaa eri parametria kuin ensimmäinen sähköinen mittauselin (5, 6 tai 1, 6), jolloin mittauselimet ovat sellaiset, että toinen mittaa nesteen ominaisuuksia suhteellisella ja toinen absoluuttimenetelmällä siten, että toinen mittauselimistä (5, 6) on herkkä dielektrisyysvakion muutoksille ja toinen mittauselin on herkkä veden suhteelliselle pitoisuudelle.

10. Patenttivaatimuksen 9 mukainen laitteisto t u n n e t t u siitä, että dielektrisyysvakion muutoksille herkkä mittauselin (5, 6) on muodostettu kahdesta toistensa lomiin sijoitetusta sormielektrodista (5, 6).

11. Patenttivaatimuksen 9 tai 10 mukainen laitteisto, t u n n e t t u siitä, että toinen dielektrisyysvakion mittaukseen osallistuvista elektrodeista (6) muodostaa osan suhteellisen pitoisuuden mittaelektrodiparista (1, 6).

12. Patenttivaatimuksen 9 mukainen laitteisto, t u n n e t t u siitä, että dielektrisyysvakion muutoksille herkkä mittauselin on muodostettu koaksiaalisesta rakenteesta, jossa toinen elektrodi muodostuu keskitapista ja vaippa on verkkomainen ja nestettä läpäisevä.

13. Patenttivaatimuksen 9 mukainen laitteisto, t u n n e t t u siitä, että mittauselimet, jotka on sovitettu mittaamaan veden suhteellista pitoisuutta, sisältävät apuväliainetta, joka kykenee imeyttämään mitattavassa nesteessä olevaa vettä.

14. Patenttivaatimuksen 13 mukainen laitteisto, t u n n e t t u siitä, että apuväliaine on polymeeriohutkalvo.

15. Patenttivaatimuksen 13 tai 14 mukainen laitteisto, t u n n e t t u siitä, että se käsittää elimet apuväliaineen dielektrisyysvakion määrittämiseksi apuväliaineen vesipitoisuuden määrittämistä varten.

(57) Tiivistelmä:

Keksintö koskee menetelmää ja laitteistoa nesteen vesipitoisuuden mittausta varten. Menetelmän mitataan nesteen ominaisuutta sähköisesti yhdellä parametrilla. Keksinnön mukaan nesteen ominaisuuksia mitataan ainakin likimain samanaikaisesti myös toisella sähköisellä menetelmällä, jolloin nesteen ominaisuuksia mitataan suhteellisella ja absoluuttimenetelmällä.

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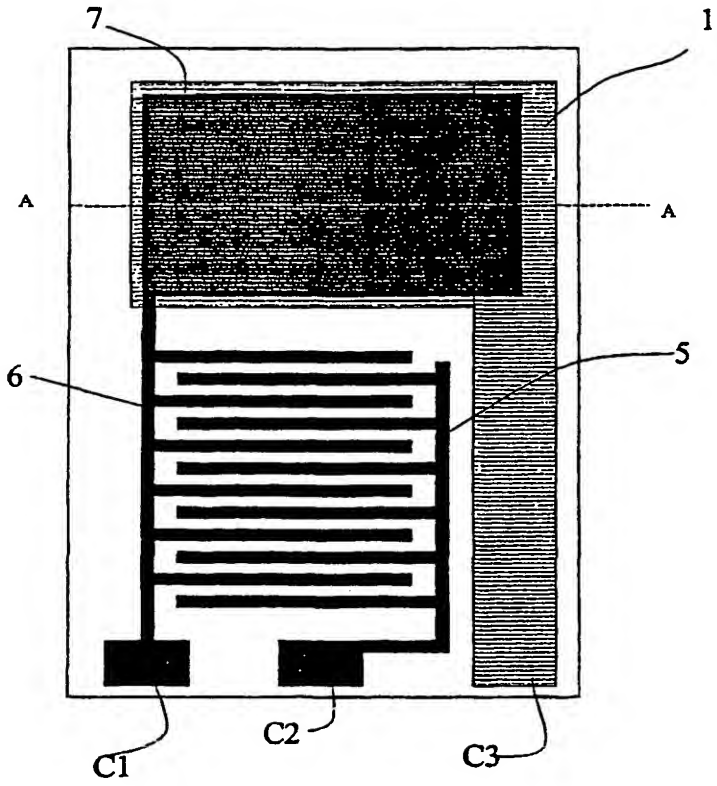
(54) Title: METHOD AND APPARATUS FOR MEASURING WATER CONTENT



(57) Abstract: The invention relates to a method and apparatus for measuring the water content of a liquid. In the method, a property of the liquid is measured electrically for one parameter. According to the invention, the properties of the liquid are measured at least substantially simultaneously by another electrical method, too, whereby the properties of the liquid are measured using both a relative-value and an absolute-value measurement method.

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METHOD AND APPARATUS FOR MEASURING WATER CONTENT

The invention relates to a method according to the preamble of claim 1 for measuring the water content of a liquid.

The invention also relates to an apparatus for measuring the water content of a liquid.

US Pat. No. 5,331,287 describes a sensor, wherein interdigitated electrodes (finger electrodes) are coated with a conducting polymer. Water contained in the oil hydrates the polymer and thus modifies its conductivity. Also detects possible acids by way of protonation.

US Pat. No. 5,642,098 discloses a ring oscillator circuit, wherein electrical properties of the oil are measured with a number of measurement heads which measure the same parameter.

US Pat. No. 5,644,239 measures the electrical conductivity of a liquid (oil) at two elevated temperatures. The technique may be complemented with a possible optical measurement of oil opacity. A "figure of quality" may then be computed for the oil from these parameters.

US Pat. No. 5,656,767 describes a sensor system for measuring the change of an electrical parameter value (e.g., capacitance) in oil as a function of time. The same oil at a clean (dry) state may be used as a reference value. The same technique may be varied in multiple ways, e.g., by heating the oil sample.

Conventional techniques are handicapped in many aspects. Common methods for sensing absolute water volume content over the entire range of 0-100 % are the measurement of the dielectric coefficient and measurement of IR absorption. Both of these methods have in common that they require a zeroing step of the measurement system, whereby the reading must be reset to zero water content when the sensor is

brought to measure an entirely dry (water-free) liquid. This step can be accomplished as a discrete zeroing operation or by using a sample of entirely dry oil in the sensor as a reference.

An additional complication arises therefrom that such a zero setting is typically dependent on the temperature.

Also other factors besides the water content may affect the zero-value with the aging of the liquid.

Methods measuring the absolute water content are favored at high water contents (in the order of several per cent).

At lower water contents, problems generally arise from the marginal detection threshold and offset uncertainty (error of zero setting).

A relative value (aw) measurement method gives information on the water content value in relation to that of a fully saturated situation. However, a conversion to the volume percentage value of absolute water content remains undefined unless a conversion factor for the liquid being measured is known. The aw measurement method is suitable for use at low water content levels (nonsaturated and not emulsified), whereby the measurement has a sufficiently high sensitivity. Moreover, the method is free from zeroing problems.

It is an object of the present invention to overcome the drawbacks of the above-described techniques and to provide an entirely novel type of method and apparatus for measuring the water content of a liquid.

The goal of the invention is achieved by way of measuring the water content of the oil/liquid using two different methods simultaneously, whereby the measurement technique is based on an absolute value measurement method complemented with a relative value measurement method.

More specifically, the method according to the invention is characterized by what is stated in the characterizing part of claim 1.

Furthermore, the apparatus according to the method is characterized by what is stated in the characterizing part of claim 9.

The invention offers significant benefits.

The combination of an absolute value measurement method with a relative value measurement method (aw-type of measurement) makes it possible to eliminate the need for a zeroing step in the absolute value measurement.

By way of performing a sequence of rapidly repeated measurements at different temperatures, it is also possible to eliminate errors caused by temperature variations.

In the following, the invention will be examined in more detail by means of exemplifying embodiments illustrated in the appended drawings, in which:

FIG. 1 shows a top view of an embodiment of an electrode structure according to the invention; and

FIG. 2 shows a sectional view of the sensor structure of FIG. 1 along line A-A.

As shown in FIGS. 1 and 2, the embodiment according to the invention can be implemented using a structure, wherein onto the surface of a substrate 4 is formed a combination of three electrodes. The surface of the substrate 4 has directly deposited thereon a pair 3 of bottom electrodes formed by electrodes 5 and 6. In the illustrated case, the electrodes are shaped into finger electrodes, more specifically disposed as interdigitated electrodes, whereby the interelectrode surface is maximized by using an electrode structure having the finger electrodes displaced between each other. The length of the adjacent edges of the interdigitated electrodes 5 and 6 is equivalent to

the area of superimposed electrodes in a planar capacitor. The width and interelectrode gap of the electrodes 5 and 6 typically are in the range of 5 to 500 micrometers. In addition to its interdigitated finger electrode portion, the electrode 6 has a planar area 7. Furthermore, the electrodes 5 and 6 include contact pad areas C1 and C2 for connection of the electrodes to measurement means. Onto the bottom electrode pair 3 is deposited a polymer layer 2 having a thickness of 0.5-5 micrometer typical. The area of the polymer layer 2 may also be extended over the interdigitated finger electrode structure 5 and 6, whereby it also functions as a passivation layer and reduces the effect of conducting particles contained in the liquid sample on the measurement result. Onto the polymer layer 2 is deposited a water-permeable top electrode 1 with a contact pad area C3 for external connections. The top electrode 1 is aligned above the rectangular solid area 7 of the electrode 6 in order to form a planar capacitor structure.

The structure illustrated in FIGS. 1 and 2 is utilized as follows. The dielectric coefficient of the liquid under measurement is measured over the contacts C1 and C2 of the electrodes 5 and 6. Respectively, the relative value measurement is performed over the electrodes 6 and 1, that is from the contacts C1 and C3.

Advantageously, the liquid whose water content is measured is oil, but the water content measurement according to the invention may also be performed on other liquids such as a hydraulic fluid, gasoline or a coolant as well.

According to the invention, the measurement of the activity of water can be carried out as follows.

Firstly, it must be noted that the water activity measurement is only an exemplifying embodiment of the relative value measurement technique according to the invention.

As shown in FIGS. 1 and 2, the sensor may comprise a polymer layer 2 deposited between two electrodes as an element, whose absorbency of water is a function of the activity of water in its immediate environment. Typically, such sensors are used

as relative humidity transducers, for example. This type of measurement method is characterized in that the measurement result indicates the degree of water activity, that is:

$$aw = F(ppm/ppm_s(T)), \quad (1)$$

where

ppm = volumetric proportion of water in solution$\times 10^6$

ppm_s = volumetric proportion of water in saturated solution$\times 10^6$

The function F may for example be assumed to have a linear nature, whereby:

$$aw = ppm/ppm_s(T) \quad (2)$$

The value of aw varies from 0 (entirely dry liquid) to 1 (entirely saturated water solution).

Hence, a mere water activity measurement gives information on how close the situation is either to an emulsified state or a water-separation state. However, when the state of emulsification or water separation is reached, the value of water activity becomes very close to 1, whereby no information on the state of the liquid can be obtained. Nevertheless, the method can render at values of $aw < 0.9$ in a very sensitive manner such oil/liquid-independent information that, for example, is related to the lubrication properties of the measured sample.

At room temperature, the value of ppm_s may vary from 20 ppm for a basic oil having no additives to values above 10,000 ppm for lubrication oils rich with additives.

Next, the measurement technique of the dielectric coefficient is elucidated in more detail. The measurement of the dielectric coefficient is only one exemplifying

embodiment of the absolute-value concentration measurements possible within the scope of the invention.

In the measurement of the dielectric coefficient of a liquid , the sensor may be implemented either using the interdigitated electrode (finger-electrode) structure according to FIGS. 1 and 2 or, alternatively, formed into a coaxial pair of electrodes brought into contact with the liquid to be measured. The output signal of the sensor is dependent on both the dielectric coefficient and water content of the liquid under measurement:

$$\varepsilon_r = \varepsilon_0 + F(ppm) \quad (3)$$

where

ε_0 = dielectric coefficient of entirely dry liquid,

F(ppm) = a function dependent on the water content. Over a limited range of water content, the function may be assumed to be linear, that is:

$$\varepsilon_r = \varepsilon_0 + a \times ppm \quad (4)$$

where

a = constant independent of the liquid type.

An advantage of the dielectric coefficient measurement technique is that it covers the entire possible measurement range from 0 to 100 vol-% water. A disadvantage of the method is that its sensitivity at the low end of water content (where the greatest interest usually lies) is low and that the value of ε_0 must be known. Typically, the measurement system is calibrated using dehydrated oil as a standard.

If both of the above-described measurement techniques are employed simultaneously, a number of different calibration techniques can be used for a given liquid.

If the liquid is known by the value of its $ppm_s(T)$, the following approach is possible:

First, the values of aw and ε_r are measured simultaneously. If aw is less than 1, formulas 2 and 4 may be assumed to be valid.

Then, the combination of formulas 2 and 4 can be solved for ε_0 and ppm. It is also possible to estimate the value of $ppm_s(T)$ if the type of the liquid is known, whereby the result thus obtained, however, remains slightly more inaccurate.

If the value of $ppm_s(T)$ of the liquid is unknown, the following procedure can be carried out:

The sensor output is measured at two (unknown) water content values. If the value of aw is smaller than 1 in both cases, an equation group of four equations and four unknown variables is obtained, which means the equations can be solved in unique manner. Assigning subindices 1 and 2 for the measurement results of the two sessions, respectively, the following formula can be written:

$$\varepsilon_0 = (aw_2 \times \varepsilon_{r1} - aw_1 \times \varepsilon_{r2})/(aw_2 - aw_1) \qquad (5)$$

This procedure may also be arranged to take place automatically during the continuous function of the measurement apparatus if the water content of the liquid under measurement varies.

If the measurement data is collected by more than two pairs of values, the unknown terms can be fitted to the data using, e.g., the least squares method.

The benefit of the latter technique is that possible changes in the values of ε_0 or $ppm_s(T)$ due to temperature variations or aging/soiling of the liquid can be compensated for. In fact, the changes detected in ε_0 serve as an indicator of aging in oil.

If the temperature of an oil sample or, respectively, of a sample flow, is changed so rapidly that the water content of the sample can be assumed to stay substantially unchanged, it is possible to determine the temperature dependence of the dielectric coefficient of an entirely dry liquid by way of measuring essentially simultaneously the ε_r and temperature of the liquid at at least two temperatures.

For example it can be assumed assuming that ε_0 is a linear function with temperature:

$$\varepsilon_r = b0 + b1 \times T + a \times ppm \qquad (6)$$

whereby the following formula can be formed

$$\varepsilon_r(T2) - \varepsilon_r(T2) = b1 \times (T2 - T1) \qquad (7)$$

wherefrom the coefficient b1 can be solved. Also in this case, it is possible to collect values at a greater number of temperatures and then fit the measurement results with the help of the least squares method. This technique gives a continuously reliable parameter estimate value for ε_0 as the temperature varies.

Also the temperature dependence of $ppm_s(T)$ can be determined simultaneously. Over a limited temperature range, a general assumption may be made as:

$$ppm_s(T) = c0 \times e^{(C1 \times T)} \qquad (8)$$

where

c0 = value of ppm_s at T = 0 °C

c1 = coefficient of temperature dependence.

Then, the value of c1 can be solved by way of measuring aw at at least two temperatures with the assumption that the water content of the liquid remains unchanged during the measurements:

$$c1 = LN(aw1/aw2)/(T2-T1) \quad (9)$$

Advantageously, these two determinations may be carried out simultaneously.

According to a preferred embodiment of the invention, the zeroing operation is performed automatically each time the measurement of aw gives a sufficiently low value. The lower the value of aw the more accurate the zeroing operation. The uncertainty of the method is associated with the value of $ppm_s(T)$ that is dependent on the type of liquid under measurement and thus can be obtained by an "intelligent guess".

According to another preferred embodiment of the invention, two samples of the liquid/oil having different water contents are taken. Then, the measurement system may intentionally be set to measure two samples of different water contents or, alternatively, gradual accumulation of data from the measured process is utilized, whereby the natural variation of water content in the monitored process is availed of. This approach also gives a value for $ppm_s(T)$ on the basis of which it is possible according to the invention to compute from the measured value of aw the correct value of ppm without resorting to an "intelligent guess".

If a continuous data collection from the monitored process is performed using simultaneously a sliding-window technique for "dumping" obsolete data, it is also possible to compensate for changes in both the value of ppm_s and ε_0 due to aging of the liquid/oil.

In the case that the process also is subjected to temperature changes, the temperature dependencies of ppm_s and ε_0 can also be resolved.

What is claimed is:

1. Method for measurement of water content of a liquid, in which method a property of the liquid is measured electrically for one parameter,

- the properties of the liquid are measured at least substantially simultaneously also by another electrical method, whereby the properties of the liquid are measured using both a relative-value measurement method and an absolute-value measurement method resulting in the measurement of the liquid for its dielectric coefficient and relative water content

c h a r a c t e r i z e d in that

- said measurement is repeated at two different temperatures in a so rapid succession that the water content of the liquid may be assumed to stay at least substantially constant.

2. Method according to claim 1, c h a r a c t e r i z e d in that the temperature dependence of the dielectric coefficient of an entirely dry liquid is determined by measuring essentially simultaneously the ε_r and temperature of the liquid at at least two temperatures.

3. Method according to claim 1 or 2, c h a r a c t e r i z e d in that said relative water content measurement is carried out using a capacitive sensor.

4. Method according to any one of foregoing claims, c h a r a c t e r i z e d in that changes in the results of water content measurement due to aging of the liquid are compensated for by virtue of using only the most recent data of the measurement history for the compensation for changes in the response of the measurement system.

5. Method according to any one of foregoing claims, c h a r a c t e r i z e d in that the aging of said liquid, advantageously oil, is indicated on the basis of changes in the value of ε_0.

6. Method according to any one of foregoing claims, c h a r a c t e r i z e d in that, in the measurement of relative water content, an auxiliary medium is used for absorbing thereto the water contained in the liquid under measurement.

7. Method according to claim 5, c h a r a c t e r i z e d in that said auxiliary medium is a thin-film polymer layer.

8. Method according to claim 5 or 6, c h a r a c t e r i z e d in that the water content of said auxiliary medium is determined by way of measuring its dielectric coefficient.

9. Apparatus for measurement of the water content of a liquid, said apparatus comprising one electrical sensor means (5, 6 or 1, 6) for measuring the water content of a liquid, which apparatus includes

- a second electrical sensor means (1, 6 or 5, 6) for measuring the water content of a liquid, said second sensor means (1, 6 or 5, 6) measuring a different parameter than that measured by said first electrical sensor means (5, 6 or 1, 6), said sensor means being such that one of them measures the properties of the liquid by a relative-value measurement method and the other by an absolute-value measurement method, whereby one sensor means (5, 6) is sensitive to changes in the dielectric coefficient and the other sensor means is sensitive to the relative water content,

c h a r a c t e r i z e d in that

- the sensor means adapted for measuring the relative water content contain an auxiliary medium capable of absorbing water contained in the liquid under measurement.

10. Apparatus according to claim 9, c h a r a c t e r i z e d in that said sensor means (5, 6) sensitive to changes in dielectric coefficient is formed by two interdigitated finger electrodes (5, 6).

11. Apparatus according to claim 9 or 10, c h a r a c t e r i z e d in that one electrode (6) of the sensor pair adapted to perform the measurement of dielectric coefficient also forms a part of the measurement electrode pair (1, 6) adapted to perform the measurement of the relative water content.

12. Apparatus according to claim 9, c h a r a c t e r i z e d in that the sensor means sensitive to changes in the dielectric coefficient is formed by a coaxial structure, wherein one electrode is formed by a center pin and the jacket has a net-like structure and is permeable to water.

13. Apparatus according to claim 12, c h a r a c t e r i z e d in that said auxiliary medium is a thin-film polymer layer.

14. Apparatus according to claim 12 or 13, c h a r a c t e r i z e d in that the apparatus contains means adapted to measure the dielectric coefficient of said auxiliary medium whereupon the relative water content of said auxiliary medium can be determined.

[57] **Abstract**

The invention relates to a method and apparatus for the measuring the water content of a liquid. In the method, a property of the liquid is measured electrically for one parameter. According to the invention, the properties of the liquid are measured at least substantially simultaneously by another electrical method, too, whereby the properties of the liquid are measured using both a relative-value and an absolute-value measurement method.

(FIG. 1)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 00/00542

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G01N 27/02, G01N 27/22, G01N 33/28
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 9923469 A1 (MULTI-FLUID INC.), 14 May 1999 (14.05.99), page 2, line 15 - line 17; page 3, line 24 - line 30; page 13, line 1 - line 21, page 16, line 14 - line 18	1-2,4-5,9-11
A	--	3, 6-8,12-15
A	US 5331287 A (FREDERID G. YAMAGISHI ET AL), 19 July 1994 (19.07.94)	6-8,10,13-15
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A	US 4129501 A (EDWARD M. HAYNES), 12 December 1978 (12.12.78)	6-8,13-15
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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 October 2000	26 October 2000 (26.10.00)
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Jonas Andersson/GH Telephone No. +46 8 782 25 00

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 00/00542

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	DE 19647201 C1 (KIMMERLE, KLAUS, DR,-ING ET AL), 12 February 1998 (12.02.98)	10
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Information on patent family members

03/10/00

International application No.
PCT/FI 00/00542

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